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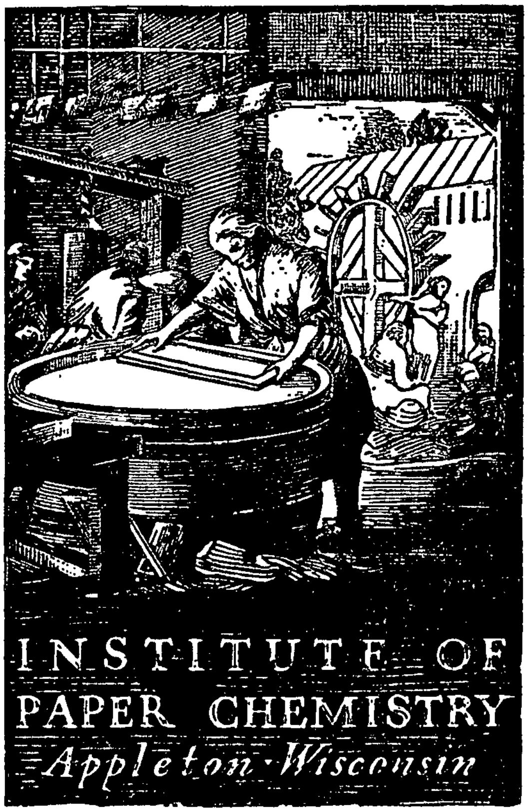

EFFECT OF DROP TEST UNITS ON CORRELATION OF SACK PERFORMANCE WITH PAPER PROPERTIES

Project 2033

Report Twenty-Three

A Progress Report

to

MULTIWALL SHIPPING SACK
PAPER MANUFACTURERS

October 16, 1962

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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Albemarle Paper Manufacturing Co.

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TABLE OF CONTENTS

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

EFFECT OF DROP TEST UNITS ON CORRELATION OF SACK PERFORMANCE WITH PAPER PROPERTIES

SUMMARY

Drop test results may be expressed in terms of the number of drops which the sack survives (safe drops) or in terms of the accumulated safe inches of fall. In a constant height drop the two systems are equivalent; however, in a progressive height drop test the two systems are nonlinearly related. For many purposes either measure may be satisfactorily used; however, in correlating progressive height sack performance with paper properties the drop test units may influence the type of function required to best fit the data.

To illustrate the above, the progressive height data from the recent fabrication study were recalculated in terms of safe drops rather than the safe inch units employed in past work. The drop test results were then correlated with T.A. impact fatigue and with machine and cross-machine T.E.A. These correlations were then compared with similar correlations developed in Progress Report 21 where the drop test results were expressed in terms of safe inches. The change in drop test unit from safe inches to safe drops had the effect of markedly increasing the predictive accuracy of the regression equations--from about 16% to 9 or 10% on the average. Therefore, based on these results, expression of progressive height drop results in safe drops rather than safe inches appears to be advantageous. Past work, such as that reported in Progress Report 21, should be reinterpreted in this light.

A similar analysis was carried out for constant height butt drop. As expected, the drop test units had no effect on either the correlation coefficient or predictive accuracy.

INTRODUCTION

In progressive height drop tests, the drop height is increased on each drop up to some maximum height, usually 120 inches. For example, in the progressive height face drop tests carried out on this project, the initial drop height was 24 inches and the height was increased by 6 inches on each succeeding drop up to a maximum of 120 inches. Each sack which survived the 17 drops required to reach a drop height of 120 inches was repeatedly dropped from 120 inches until failure occurred.

The results of the test may be expressed in at least two ways, namely,

(a) accumulated safe inches of drop, and

(b) number of safe drops, i.e., drops to failure minus one.

The relationship between the two ways of expressing the results is illustrated in tabular form as follows:

Drop Height, inches	Number of Drops to Failure	Number of Safe Drops	Accumulated Safe Inches, inches
24	1	0	0
30	2	1	24
36	3	2	54
42	4	3	90
48	5	4	132
54	6	5	180
--	--	--	--
--	--	--	--
--	--	--	--
120	17	16	1104
120	18	17	1224

It is evident that the two measures are nonlinearly related through the range of 16 safe drops. For example, compare two sacks giving two and four safe drops, respectively, a ratio of 2:1. In terms of safe inches the values for the two sacks would be 54 and 132--a ratio of 2.45:1. Because the two measures are nonlinearly related, averages in one set of units cannot be simply converted to the other set of units. For example, assume that five sacks were tested in a progressive height drop test with the following results:

Sack No.	Safe Drops	Safe Inches
1	1	24
2	2	54
3	3	90
4	4	132
5	5	180
Average	3	96

As may be noted, the average of 96 safe inches is somewhat greater than the 90 safe inches which would be obtained by simply converting the average of three safe drops to safe inches.

While counting the number of safe drops disregards the increase in impact severity as drop height increases, expression of results in safe inches attempts to make allowance for this factor. The basic assumption made is that impact severity will be directly proportional to the potential energy possessed by the sack on each drop, i.e., to the drop height when sack weight is constant.

Either measure may be used to express drop test results and, for many purposes, one measure may be as good as the other. This may not hold true, however, when it is desired to statistically relate sack drop performance to sack paper properties. The fact that the two measures are nonlinearly related may, at least, influence the type of function required to best fit the data.

For this project, drop test results have been expressed in safe inches in all past work with one exception--in Progress Report 22 all statistical work was performed using face drop results expressed in safe drops (1). In contrast, in Progress Report 21 all correlations were carried out using drop test results expressed in safe inches (2). Comparison of the results discussed in the two reports suggested that a number of the correlations obtained in Report 21 should be re-evaluated after changing the units of the dependent variable. This report summarizes the results obtained.

DISCUSSION OF RESULTS

Progressive height face and constant height butt drop results from the recent fabrication study are tabulated in Table I in terms of both safe inches and safe drops. The safe drop values tabulated in Table I are the average drops experienced in testing and therefore do not correspond to a calculated number of safe drops based on the average safe inches. The relationship between the two measures is illustrated in Fig. 1 for both types of drop test. As mentioned previously, the relationship between progressive height face drop results expressed in safe inches and safe drops is nonlinear. In contrast, the corresponding graph for butt drop--a constant height test--gave a linear relationship between the two measures as would be expected.

To illustrate the effect on correlations with paper properties, several functions investigated in Progress Report 21 were selected for study. They were as follows:

Progressive height face drop vs.

a) T.A. impact fatigue ($\underline{T}_{\underline{a}}$)

b) Machine and cross-machine T.E.A. (Tensile energy absorption) ($\underline{W}_{\underline{x}}$ and $\underline{W}_{\underline{y}}$)

Butt drop vs.

a) Machine and cross-machine T.E.A. ($\underline{W}_{\underline{x}}$ and $\underline{W}_{\underline{y}}$)

Correlations were performed with the drop test values expressed in safe drops and the results were compared with those reported in Progress Report 21 where the drop test values were expressed in safe inches. Table II summarizes the correlations for progressive height face drop. As may be noted in the table, correlations were performed for the following data subdivisions:

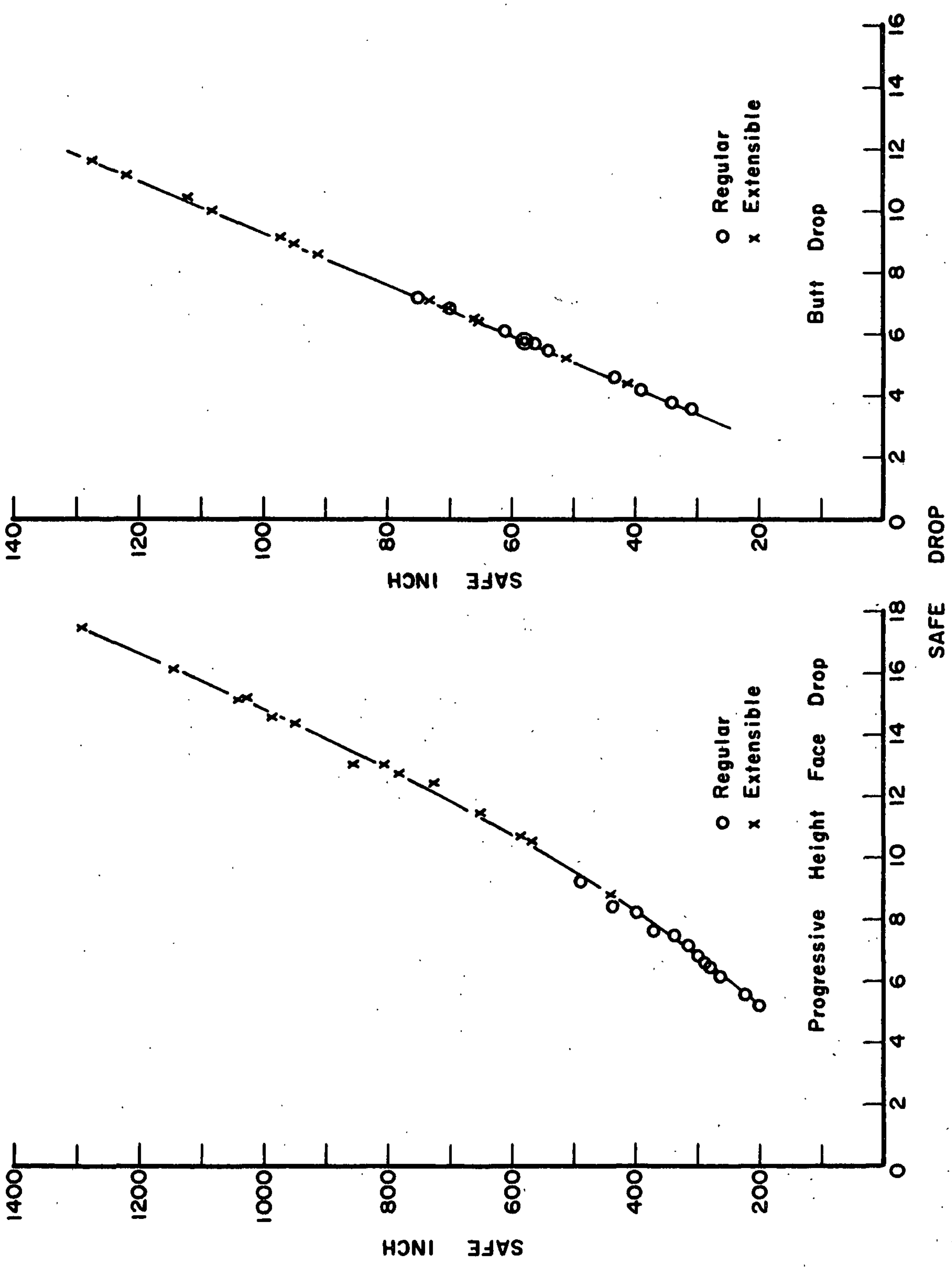

Figure 1. Relationship Between Drop Test Units for Progressive Height Face and Constant Height Butt Drop

TABLE I

DROP TEST RESULTS FOR REGULAR AND EXTENSIBLE KRAFT SACKS

Run	Progressive Height Face Drop, safe inch	Progressive Height Face Drop, safe drop	Butt Drop, safe inch	Butt Drop, safe drop
		Regular Kraft		
AA	401	8.2	70	5.9
BB	370	7.6	43	3.6
CC	435	8.4	61	5.1
DD	288	6.6	39	3.2
EE	201	5.2	34	2.8
FF	222	5.5	31	2.6
GG	316	7.1	54	4.5
HH	296	6.8	57	4.8
II	338	7.5	58	4.8
JJ	487	9.2	75	6.2
KK	262	6.1	58	4.8
LL	281	6.4	56	4.7
		Extensible Kraft		
MM	855	13.0	108	9.0
NN	987	14.5	91	7.6
OO	1144	16.1	122	10.1
PP	781	12.7	73	6.1
QQ	1023	15.1	97	8.1
RR	1288	17.4	127	10.6
SS	438	8.8	41	3.4
TT	565	10.5	51	4.2
UU	585	10.7	59	4.9
VV	1038	15.1	112	9.4
WW	807	13.0	66	5.5
XX	650	11.4	65	5.4
YY	727	12.2	70	5.8
ZZ	951	14.3	95	7.9

84.6/12 = 7.05
530 = 4.4

1748/14 = 12.5
980/14 = 7.0

TABLE II

COMPARISON OF CORRELATIONS BASED ON PROGRESSIVE HEIGHT FACE DROP EXPRESSED IN EITHER SAFE INCHES OR SAFE DROPS

Drop Test Units	Data Subdivision	N	Regression Equation	Correlation Coefficient	Av. Diff., %[a]	Per Cent of Comparisons Within ± 10%	± 15%	± 25%
Safe drops	Regular	12	$y = 5.30 + 0.110\ T_a$	0.71	9.6	67	75	92
	Extensible	14	$y = 5.36 + 0.144\ \overline{T}_a$	0.82	8.8	50	71	86
	Regular plus extensible	26	$y = 4.72 + 0.154\ \overline{T}_a$	0.95	9.4	50	85	96
	Fabrication study I	20	$y = 5.09 + 0.143\ \overline{T}_a$	0.70	10.9	55	75	90
	Fab. I + Fab. II	46	$y = 4.83 + 0.152\ \overline{T}_a$	0.93	10.1	54	78	94
Safe drops	Regular	12	$y = -0.204 + 11.326\ W_x + 7.582\ W_y$	0.84	7.4	67	83	100
	Extensible	14	$y = -0.901 + 4.114\ W_x + 15.595\ \overline{W}_y$	0.72	10.8	64	71	93
	Regular plus extensible	26	$y = -0.341 + 5.202\ \overline{W}_x + 12.240\ \overline{W}_y$	0.93	10.2	69	77	96
	Fabrication study I	20	$y = 3.260 + 4.981\ \overline{W}_x + 6.237\ W_y$	0.53	11.9	55	75	85
	Fab. I + Fab. II	46	$y = 1.386 + 5.237\ \overline{W}_x + 9.206\ \overline{W}_y$	0.90	11.6	57	85	89
Safe inches	Regular	12	$y = 201.5 + 7.78\ T_a$	0.69	15.2		58	75
	Extensible	14	$y = 50.7 + 14.6\ T_a$	0.82	15.1		57	71
	Regular plus extensible	26	$y = 114.0 + 13.4\ \overline{T}_a$	0.94	16.8		50	73
	Fabrication study I	20	$y = 166.3 + 10.9\ \overline{T}_a$	0.72	16.7		65	75
	Fab. I + Fab. II	46	$y = 115.2 + 13.3\ \overline{T}_a$	0.93	16.7		59	76
Safe inches	Regular	12	$y = -190.8 + 781\ W_x + 555\ W_y$	0.84	12.1		67	92
	Extensible	14	$y = -599.4 + 385\ \overline{W}_x + 1676\ W_y$	0.73	17.9		64	71
	Regular plus extensible	26	$y = -361.6 + 430\ \overline{W}_x + 1169\ \overline{W}_y$	0.92	19.1		62	77
	Fabrication study I	20	$y = 30.9 + 394\ W_x + 459\ W_y$	0.53	18.9		50	80
	Fab. I + Fab. II	46	$y = -169.1 + 460\ W_x + 771\ W_y$	0.89	19.0		48	76

[a]Based on observed values as reference.

1) Regular--12 regular kraft combinations from recent fabrication run (fabrication study II).

2) Extensible--14 extensible kraft combinations from recent fabrication run.

3) Regular plus extensible--combined data from recent fabrication run.

4) Fabrication study I--data obtained in first fabrication run [see Progress Report 12--Reference (3)].

5) Fab. I and Fab. II--combined data from both fabrication studies.

When the correlations are examined it may be noted that the correlation coefficients were not affected significantly by the units of the dependent variable. In contrast, the prediction efficiency was markedly affected with the better predictions being obtained when the drop results were expressed in safe drops rather than safe inches. This is illustrated by the average percentage difference between predicted and observed drop test values. For example, the following values are abstracted from Table II for the linear correlations with T.A. impact fatigue.

Data Subdivision	Average Difference Between Predicted and Observed Drop Test Values, %: Drop Test in Safe Inches	Drop Test in Safe Drops
Regular	15.2	9.6
Extensible	15.1	8.8
Regular plus extensible	16.8	9.4
Fab. Study I	16.7	10.9
Fab. I plus Fab. II	16.7	10.1

Thus, changing drop test units from safe inches to safe drops had the effect of increasing the average prediction accuracy from about 16% down to 9 or 10%. It appears that safe drop basis underestimates when compared to safe inches. Therefore, there appears to be a real advantage in expressing progressive height drop results in terms of safe drops where correlation with sack paper characteristics are concerned. The conclusions in Report 21 with respect to the progressive height face drop correlations should be modified, therefore, in the direction of increased prediction efficiency.

A similar but less extensive analysis was carried out using butt drop results. The results are shown in Table III. As would be expected, the drop test units had no effect on either the correlation coefficient or the prediction accuracy.

TABLE III

COMPARISON OF CORRELATIONS BASED ON BUTT DROP EXPRESSED IN EITHER SAFE DROPS OR SAFE INCHES

Drop Test Units	Data Subdivision	$\underline{N}$	Regression Equation	Correlation Coefficient	Av. Diff., %[a]	Per Cent of Comparisons Within ± 10%	± 15%	± 25%
Safe inches	Regular	12	$\underline{B} = -24.4 + 64.0\ \underline{W_x} + 121.0\ \underline{W_y}$	0.86	10.5	--	83	92
	Extensible	14	$\underline{\overline{B}} = -90.4 + 31.9\ \underline{\overline{W}_x} + 233.9\ \underline{\overline{W}_y}$	0.82	17.8	--	64	86
	Regular plus extensible	26	$\underline{\overline{B}} = -38.0 + 14.2\ \underline{\overline{W}_x} + 182.8\ \underline{\overline{W}_y}$	0.86	16.8	--	58	85
	Fabrication study I	20	$\underline{\overline{B}} = 4.1 - 34.8\ \underline{\overline{W}_x} + 133.4\ \underline{\overline{W}_y}$	0.80	15.6	--	55	80
	Fab. I + Fab. II	46	$\underline{\overline{B}} = -25.6 + 16.9\ \underline{\overline{W}_x} + 155.0\ \underline{\overline{W}_y}$	0.84	16.5	--	59	83
Safe drops	Regular	12	$\underline{B} = -2.04 + 5.25\ \underline{W_x} + 10.15\ \underline{W_y}$	0.86	10.6	50	75	92
	Extensible	14	$\underline{\overline{B}} = -7.47 + 2.61\ \underline{\overline{W}_x} + 19.50\ \underline{\overline{W}_y}$	0.81	18.1	36	64	86
	Regular plus extensible	26	$\underline{\overline{B}} = -3.17 + 1.18\ \underline{\overline{W}_x} + 15.26\ \underline{\overline{W}_y}$	0.86	16.9	35	54	85
	Fabrication study I	20	$\underline{\overline{B}} = 0.28 - 2.89\ \underline{\overline{W}_x} + 11.22\ \underline{\overline{W}_y}$	0.80	15.2	45	55	80
	Fab. I + Fab. II	46	$\underline{\overline{B}} = -2.17 + 1.40\ \underline{\overline{W}_x} + 12.98\ \underline{\overline{W}_y}$	0.84	16.6	39	59	83

[a]Based on observed values as reference.

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